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ARAPAHOE GLACIER IN 1903.¹

A VISIT to Arapahoe Glacier, in the cirque on the east side of Arapahoe Peak, west of Boulder, Col., in 1903, for the purpose of comparing its present condition with that existing at the time of the preceding examination, brought to light some interesting and important facts. In 1902 we were on the ice on three different days during the last week of August. In 1903 the visit was made on September 2, only one day being spent on the ice by the writer, in company with Professor A. H. Felger, of Denver. The summer of 1902 was particularly favorable for our first visit because the high temperature and preceding shortage of precipitation had caused the snow to melt from the surface of the entire glacier up to the Bergschrund, which was exposed as a great, gaping break clear across the face of the glacier; but in 1903, even at a great distance, it could be seen that snow still remained on the ice down to the main system of crevasses, while the Bergschrund was exposed for only a very short distance, which was perhaps due as much to the unusually cool spring and summer as to the greater fall of snow last winter. The greater part of the Bergschrund and many of the visible crevasses were partly or wholly filled with last year's snow, though in some cases the snow merely formed a bridge instead of filling the crevasse, which made it dangerous traveling above the line of uncovered ice.

On the whole, there was a slight increase in the height of the snow and ice along the north side and in the height of the ice along the terminal moraine, but at two points along the terminal moraine there has been a decided shrinkage during the year, which is of some importance. One such point is at the lake retained by the moraine, or rather where the central surface drainage system pours its waters into the lake, which is shown on the map (Fig. 2) and the photograph (Fig. 8) accompanying

¹ For a general account of this glacier see this JOURNAL, Vol. VIII, p. 647. For a more detailed account see Vol. X, p. 839.

Dr. Fenneman's paper. The other point of shrinkage is where the western surface drainage breaks through the moraine. Both of these ice valleys were greatly deepened, and their sides were much steeper than last year, which suggests stream erosion as the prime cause of the change in the face of the glacier at these points. However, as the surface streams flow southward, and their valleys are consequently exposed to the full glare of the noonday sun and protected from cooling breezes, the confinement of heated air in the valleys is an element to be reckoned with in the problem of waste at these points. These surface streams on the front of the glacier are made possible by the fact that for

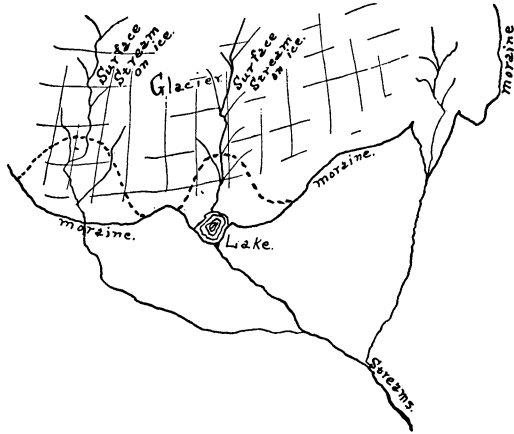


FIG. 1 — Diagram on exaggerated scale, the broken line showing change in front of glacier now apparently in progress, from erosion and melting along water courses.

some distance back from the terminus the ice is free from open crevasses into which the water arising from surface melting could otherwise plunge. Wasting at these points, while apparently gaining slightly, or at least fully holding its own, at other points along the front of the glacier shows clearly how a glacier may change the shape of its terminus, and consequently of its terminal moraine, as shown by the accompanying diagram. It is probable that the confusion of moraines several miles below the present terminus of Arapahoe Glacier, where they intersect each other at all angles, is partly due to the rapid and repeated changes in the end of the former ice tongue, as well as partly to the melting out of ice blocks in the moraine, as suggested by Dr. Fenneman.

Where the surface stream enters the terminal lake the ice is now worn to the ground moraine, so that the water issues from

beneath the ice at the upper edge of the lake loaded with rock flour, and rises milky white abruptly through the clearer water gathered from the surface, forming a striking feature not found there in 1902, when, if it found its way into the lake at all, it was so diluted before reaching the surface that it did not attract attention.

As would be expected from the deepening of the drainage valley leading into the lake, by vertical erosion, and the increase in its width by lateral erosion and melting, the area of the lake is much greater than in 1902, just as its area in 1902 was apparently greater than when examined by Professor Lee in the summer of 1900.

Another noteworthy fact is that almost the entire front of the glacier was steeper in 1903 than in 1902, upon which subject more data and accurate measurements seem necessary before a satisfactory reason may be assigned for the change.

Although the rate of flow for this glacier is unknown, it must surely be so slow as to require several years of normal or excessive precipitation or low temperature for its down-stream extension to recover from the effects of rapid waste during a series of warm, dry seasons.

An analysis of the records of the Denver, Boulder, Sugar Loaf, Moraine, and Long's Peak stations, as shown by the monthly statements of Mr. F. H. Brandenburg, Denver forecast official and section director of the Weather Bureau, indicates that from September 1, 1901, to September 1, 1902, the precipitation was far below normal and the average temperature was much above normal. On the other hand, from September 1, 1902 to September 1, 1903, precipitation was considerably above normal and average temperature was much below normal. The highest of these stations is only 8,500 feet above sea-level, and the nearest is about ten miles distant, so the figures given for the stations would not exactly apply to the glacier, the altitude of which is about 13,000 feet; but the fact that all the stations record greater precipitation and lower temperature for the latter period than for the former period makes it appear exceedingly probable that the same condition would have been shown if a rec-

ord had been kept at the glacier itself. Furthermore, the cirque containing the glacier is in full sight from the brow of University Hill in Boulder, and during the autumn of 1902, winter of 1902-3, and spring of 1903, the writer watched the peak as closely as possible, and was much impressed with the frequency with which clouds gathered in the glacial amphitheater when all was clear elsewhere. The snows began early in September and continued until late spring.

It seems possible that the significance of the silt on the morainal boulders in 1902 may have been misunderstood, as a similar condition was observed in 1903; and yet it is hardly possible that the glacier flowed out over the moraine and then melted back to the base of the moraine between September, 1902, and September, 1903. A possible explanation suggests itself. The accumulation of snow on the glacier each year is known to be enormous, a great many feet in depth. The westerly gales are known to carry from the rim of the cirque to the glacier large quantities of dust and finely comminuted vegetable matter during every dry, windy period, which periods are common in that region and at that altitude. The accumulated snows containing such dust and vegetation cover the moraine to a great depth in winter. As the snow melts in the spring, the *débris* gradually accumulates at lower and lower levels, until finally it is left as silt on the tops of the boulders and all over the moraine. Unfortunately, we brought none of it with us, and failed to make a minute examination of it under a good lens. The cause may be sufficient to account for the phenomena, but the subject is worthy of more extended investigation before announcing definite conclusions.

JUNIUS HENDERSON.

MUSEUM, UNIVERSITY of COLORADO,
Boulder, Col.